Energy Transition of Uruguay

BY GONZALO CASARAVILLA AND RUBEN CHAER

Abstract

The change in the electricity generation matrix made in Uruguay between 2013 and 2017 and a possible future evolution are presented. The economic fundamentals that led to this change are shown, especially the reduction in cost risks in the electricity sector.

The Uruguayan Electric System has changed substantially in recent years [1]. The country transformed its generation matrix, following an optimized investment plan, in which Non-Conventional Renewable Energies (NCRE) were the protagonists. Fig. 1 shows the speed with which the transformation was carried out from 2013 to 2017.

The year 2018 can be considered as representative of the current system, after the radical transformation carried out. Fig. 2 shows the expected value of the energy generated by the different sources, being Hydraulic 49%, Wind 38%, Biomass 7%, Solar 3% and Thermal 3%. Therefore, the new generation matrix in Uruguay is 97% based on renewable energies and in particular 48% is with NCRE (Wind, Solar and Biomass).

The thermal power plants (motor generators and aero derivative turbines), in Uruguay, are mainly backup and together with the hydroelectric plants they allow to guarantee peak demand.

Uruguay developed in the 80s of the 20th century 100% of its hydroelectric generation potential at an efficient scale, thus taking the first step towards a system based on renewable energies.

In expected value, 10% of the generation is associated with occasional surpluses and is exported to neighbouring countries. If it is taken into account that the maximum demand in Uruguay is 2,200 average MW (year 2021), the 2,000 MW of the interconnection capacity with Argentina and the 570 MW of interconnection with Brazil, together allow relatively important energy exchanges for Uruguay. Take into account that the Electricity System of Argentina and Brazil are, respectively, eleven and fifty times larger than that of Uruguay.

In Uruguay, the optimal economic dispatch of generation resources is carried out by assimilating the forecast information of the water inflows to the dams and the forecasts of wind and solar generation with increasingly powerful and sophisticated tools.

There are hours or days with little wind or sun, but the energy received on a bi-monthly scale from these sources, with probability 95% exceeds 90% of its expected value, contrasting in this sense with the availability of energy of hydroelectric origin that in Uruguay has significant variability at the annual level as shown in Fig. 3. To have the same confidence margin in Uruguay for hydroelectric energy, it is necessary to average 16 years. In Fig. 3 you can also see how the 11,000 GWh of demand in 2020 would have been supplied. Note that the hydroelectricity of 2020 is located in the 5% of the driest years in the history of hydroelectric generation in Uruguay.

If the generation matrix had not been changed, thermal generation (or imports) would have reached 65% of demand, totalling 7,200 GWh.

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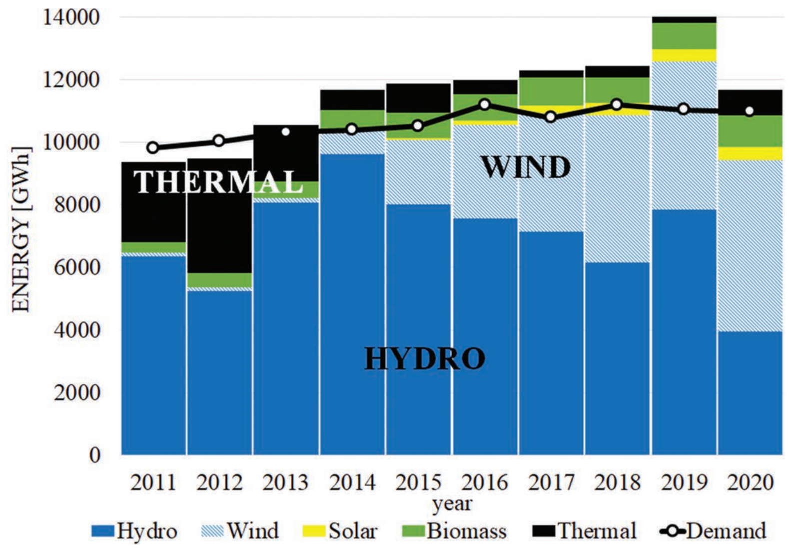

Fig. 1: Evolution of the Generation from 2011 to 2020 in Uruguay.

It can also be seen in Fig. 1 and Fig. 2 what happened in 2012, a moderately dry year and prior to changing the generation matrix. Fig. 4 shows the expenditure on the purchase of fossil fuels for electricity generation from 2010 to 2020. In 2012, 1015 MUS$ were spent on thermal generation and energy had to be imported from the region, at prices comparable to the costs of rationing, for another 369 MUS$. Between fossil

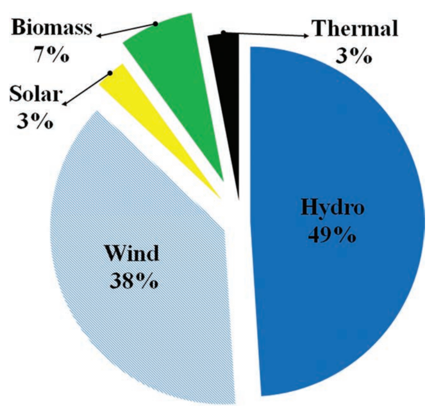

Fig. 2: Expected value of generation in Uruguay 2018.

fuels and imports, 1,384 MUS$ were spent. Said amount, for the Uruguayan economy, was extremely significant, representing 2.6% of the Gross Domestic Product in 2012. Fortunately, it was not as bad as it could have turned out. If the two main risk factors are considered, which are the hydroelectric generation of the year and the price of fossil fuels from thermal generation, the generation cost in 2012 could reach 2,400 MUS$ with a 5% risk of being exceeded. At that time, and in order to temporarily cushion this risk condition, a climatic insurance was contracted that combined the climatic aspect and the cost of a barrel of oil [2]. An Energy Stabilization Fund (ESF) was also implemented in 2011 [3]. Both instruments allowed the energy transition to be carried out with peace of mind and lost importance once the transformation was carried out. Due to the nature of the new generation matrix in Uruguay, with a high penetration of NCRE, the risk of system over-costs has been radically reduced. The climate insurance no longer makes sense to contract it and the ESF has been adapted to reflect the reduction in the need to stabilize costs.

As a result of the energy transition, the worrying Fig. 3 was replaced by Fig. 5. in which the current configuration of the Uruguayan generator park is observed. Fig. 5 shows what would happen for the year 2020 that was dry.

In 2020, a total of 11,662 GWh were generated. Thermal generation was 804 GWh which, as shown in Fig. 4, represented a cost of 99.5 MUS$, no thermal energy was exported, 514 GWh were imported, which if not imported would have also been generated with thermal power plants. Adding both values, it turns out that the equivalent thermal generation for 2020 was 1,319 GWh. The total equivalent generation was 12,176 GWh, the equivalent thermal generation being 11% of said value. Remember that for an average year the thermal generation is 3%. The drought of 2020 almost quadrupled the costs of thermal generation with respect to the expected value. But the new matrix still keeps them limited since the 1,319 GWh would be equivalent to a cost of 163 MUS$ (99.5x1,319 / 804). If the 7,200 GWh in Fig. 3 had to be generated, they would have cost 891 MUS$. It should be noted that the price of a barrel of oil in 2020 was definitely low. A risk analysis should consider values between two and three times higher, which corresponds to the 2,400 MUS$ already referred to.

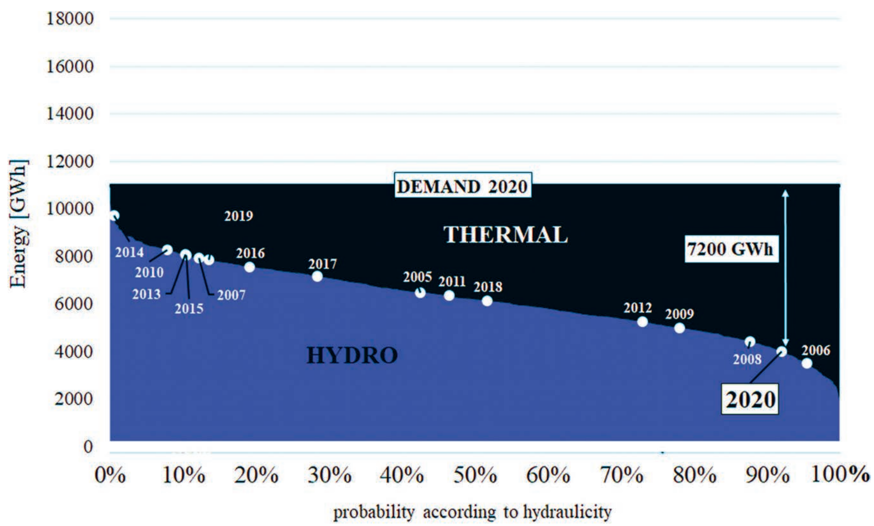

Fig. 3: Hydraulic and thermal generation expected in 2020 if the Uruguayan generation matrix and hydraulic generation verified between the years 2005 to 2020 were not changed.

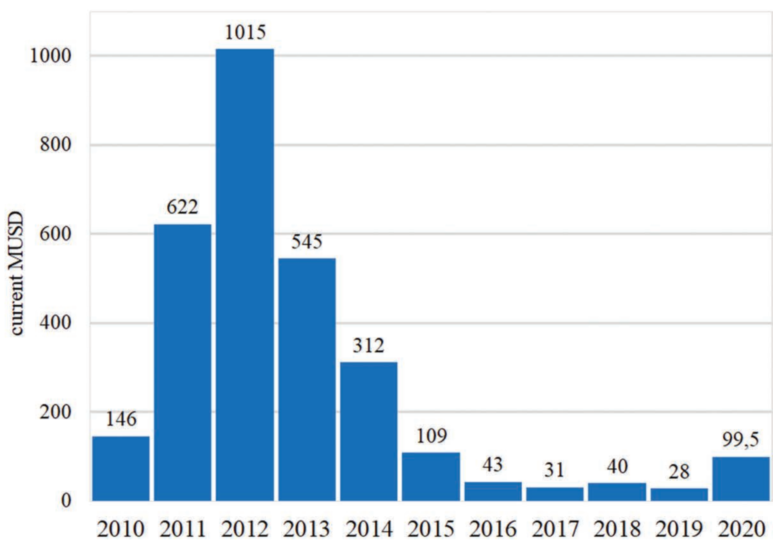

Fig. 4: Expenditure of fuels in thermal generation from 2010 to 2020.

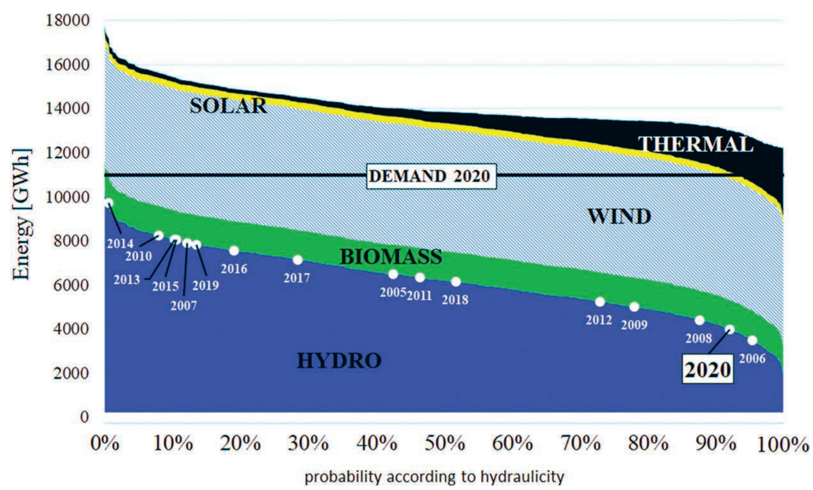

Fig. 5: Generation expected for the year 2020 for the current Uruguayan generator park and hydraulic generation verified between the years 2005 to 2020.

The cost of biomass, wind and solar generation in 2020 was 520 MUS$. It is enough to compare the 891 MUS$ with the 520 + 163 = 683 MUS$ to corroborate, even for extreme low values of a barrel of oil and not considering the income from exports, the benefit obtained from the change in the generation matrix in Uruguay.

Observe from Fig. 1 (reality) and Fig. 5 (expected values) that even in a dry year like 2020 there is export. For example, in 2020, exports reached 1,148 GWh, (almost 10% of generation) since it is associated with occasional surpluses associated with Uruguay's new generation matrix with high NCRE penetration.

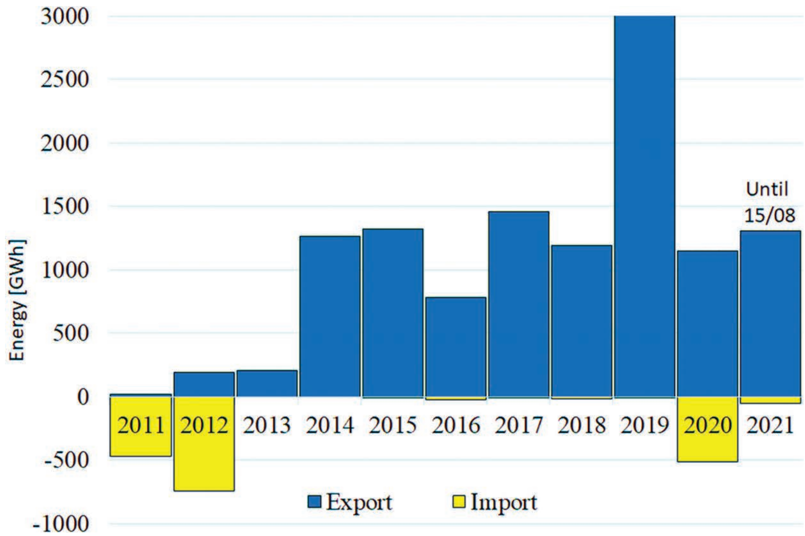

Fig. 6: Energy export and import balance from 2011 to 2021.

In Fig. 6 it is observed how Uruguay went from being a deficit country to being a net exporter, even and as already seen, under drought conditions. Note that although the year 2021 has been presenting itself as a moderate drought, as of August 15, 2021, the export balance already exceeded the expected value (compare with 2018, which is the one taken as the average year). This is due to the fact that neighbouring countries are also exposed to low hydroelectric generation, raising prices and justifying the purchase of generation at thermal power plant values. Thermal generation, as of 8/15/2021 represents 17%, which is projected at the end of the year will be a record value, possible due to the new generation matrix in Uruguay.

In recent years there has been a gradual and continuous improvement in occasional exchanges between the systems of Uruguay, Argentina and Brazil. These improvements are mainly related to flexibility in terms of being able to carry out occasional exchanges based on offers that allow taking advantage of the mutually beneficial opportunities created by renewable energies in the three systems. We can visualize it as a virtuous circle. The improvement of the market coupling in the region helps to increase the speed with which the generation matrices of Argentina and Brazil will be transformed, which in turn creates more opportunities for benefits from energy exchanges.

Thinking ahead, a possible evolution of Uruguay's optimal generation matrix is shown in Fig. 7. To optimize the expansion plan in Fig. 7, it was assumed that nothing new was installed until 2030, that all current aero derivative turbines and current motor generators are out of service due to obsolescence and that of the current thermal park, only the 540 MW Combined Cycle remains operational.

It is observed that the generation of thermal energy is increasing as we approach the year 2030. From 2030, the expansion is carried out based on Solar and Wind energy both to accompany the growth of demand and to replace wind and solar generation plants existing at the end of their useful life.

The optimum also includes the incorporation of new thermal power plants. In this case shown, a total of six aero derivative turbines of 60 MW are installed in the period studied. The previous result is consistent with the fact that the annual peak of demand, of the projection used in the optimization of the investment plan, grows on average 55 MW per year from 2030 to 2039.

This is a characteristic of the optimal expansions of systems with strong incorporation of NCRE and constant hydraulic capacity. These systems have a first stage in which the expansion with NCRE increases the firm-capacity (short-term energy availability) of the hydraulic power plants, avoiding the installation of thermal power plants. At the end of this stage, the hydroelectric plants can deliver up to their installed

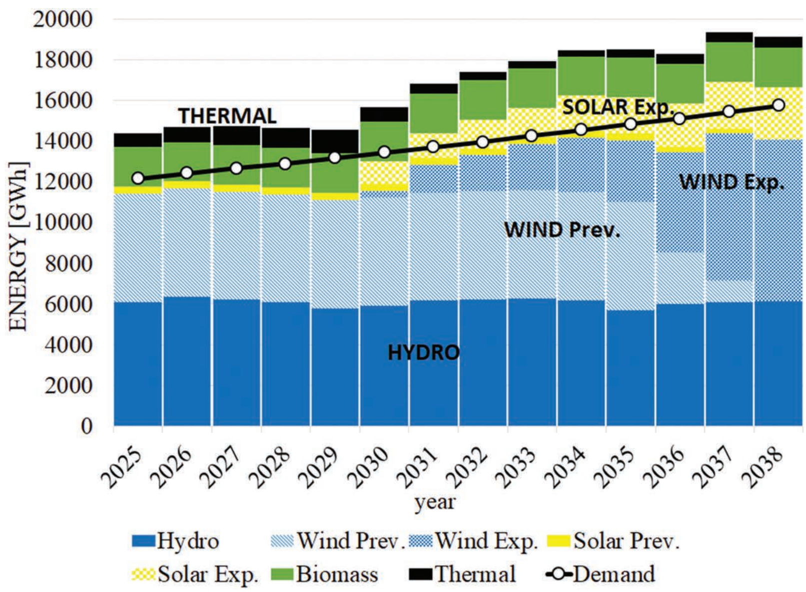

Fig. 7: Generation 2025-2039 with optimal expansion (WIND Exp. and SOLAR Exp.) from 2030 to 2039.

capacity at the times of greatest power requirements of the system. Once this limit has been reached, a second stage begins where the incorporation of more NCRE implies either the installation of peaking thermal power plants to cover the power requirements or possibly in the future control actions on possible demands with responses.

Conclusions

Uruguay has managed to complete its energy transition and its electricity generation is 97% renewable. During the 80s of the 20th century, 100% of the hydroelectric potential was developed. Between 2014 and 2017, NCRE was incorporated on a massive scale, accounting for 48% of the generation. This milestone was possible based on a multiparty political agreement in 2010 that provided the framework to turn the task into a national objective.

An attempt has been made to summarize the past, present and future of electricity generation in Uruguay with the corresponding generation matrices. The economic fundamentals of these matrices incorporate the fact that Uruguay does not have oil or natural gas deposits but has been favoured by nature with abundant resources of hydraulic, wind and solar energy.

For Uruguay, the future path is to continue incorporating NCRE. For this, more and better tools will be needed to perform the optimal dispatch of the generation resources system. It will be necessary to continue improving the forecasts of wind and solar generation as well as the flows of contributions to the dams. Optimal planning and dispatch tools will need to continue to be improved. All this is what has been done in a sovereign way in recent years. The history of having achieved in a few years the last stage of the energy transition managing a system with high penetration of NCRE augurs a promising future.

The development of NCRE and the transition of the remaining regional generation matrices are also promising. For now, each country will continue planning and guaranteeing its supply in a sovereign way. The economic rationality of the occasional exchanges is the first stage that would one day allow us to think about regional planning of infrastructures and a coordinated dispatch. But that is another story that surely needs a regional political stability that does not depend only on the electricity sector.

References

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